San Joaquin River Fall-run Chinook Salmon Population Model

External Scientific Review Form

Reviewer: #5

Review:

1. **Problem/Goals.** Is the problem that the project is designed to address adequately described? Are the goals, objectives and hypotheses clearly stated and internally consistent?

The problem is well described (based on both the VAMP annual report and the DFG).

2. **Approach.** Is the approach well designed and appropriate for meeting the objectives of the project as described in the proposal?

The available documentation clearly states that the basis for the SJR Fall-run Chinook Salmon Population Prediction Model was in response to a request from the State Water Resources Control Board (SWRCB) for the California Department of Fish and Game (DFG) to provide a recommendation for Vernalis flow objectives. Specifically, in early 2005, the DFG evaluated the 1995 Water Quality Control Plan by asking four key questions: 1) What is the current status of the SJR fall-run Chinook salmon population?; 2) What level of protection is being afforded salmon smolts out-migrating from the SJR into the South Delta?; 3) What is the status of the Vernalis Adaptive Management Plan (VAMP) experiment?; and 4) What influence does spring flow have on fall-run Chinook salmon production in the SJR? The approach outlined in the documentation and supported by the spreadsheet model is consistent with this approach and well described in the documentation. However, there is a larger issue at hand: are the four questions identified by the DFG of sufficient scope to address the challenging problem in the San Joaquin Basin, Delta, and Ocean environs?

3. **Feasibility.** Is the approach fully documented and technically feasible? What is the likelihood of success? Is the scale of the project consistent with the objectives?

The approach is generally well documented. The statistical details of the formulation of key relationships (e.g., regression equations) should be more thoroughly and formally presented. The modeling process has presented a useful framework for couching many of the factors thought to be important in fall-run Chinook production in the San Joaquin River. The document and model have largely been successful in this manner.

4. **Project Performance Evaluation Plan.** Will a monitoring plan be developed to document changes in the restored habitat over time and the response of salmonids and/or riparian vegetation to the restoration in a scientifically rigorous manner?

Sufficiency of existing monitoring is not addressed in the primary documentation. The VAMP annual report identifies the need for additional/ongoing monitoring/studies. The *overall concept of using the model to set long-term flow recommendations is not paired with a monitoring program…but such a program would be a wise investment.*

5. **Expected Products/Outcomes.** Are products of value likely from the project?

The reviewer is very pleased that DFG is taking a highly proactive approach to the VAMP process and pressing hard questions prior to the completion of the 12 year program. Development of a quantitative model to assess the response of fall-run Chinook salmon production is a valuable step in the overall recovery strategy and management of the San Joaquin River water resources and fisheries. The work completed by the Department allows additional questions to be asked and more refined hypothesis to be presented. However, the model in itself is only one aspect of a complex system. As such, the conclusion that flow recommendations can be based on the "simple spreadsheet flow-based" model is probably over-optimistic.

Modeling is a lengthy process. Not only does it take a fair amount of time to gather the data, develop the relationships, and place the whole affair into a quantitative numerical framework, but it also takes time to document the information and convey it to interested parties…and this is only the beginning. Review of model representations, processes, and data used to form fundamental relationships is not a static process – new information and interpretation continues to occur. The product developed by the Department is a valuable first step in a longer process of sharing information and ideas, modifying model relationships, conceiving of new ideas and abandoning previous held beliefs, and along the way making progress in resource management.

Additional Questions:

General:

The purpose of the model is to develop spring flow magnitude, duration, and frequency instream flow levels into the South Delta to adequately protect, and restore, fall-run Chinook salmon in the San Joaquin River basin. To accomplish this objective, please address the topics listed below for these questions:

Is the model adequate?

The model provides additional insight into the role of spring flow magnitude, duration, and frequency as these conditions relate to historical fall-run Chinook salmon in the San Joaquin River basin. Construction of the model has allowed assessment of several factors as they relate to potential impacts of increased flows on salmon. After examination of the available materials, the Reviewer identifies the role of this model as one tool that may provide insight into long term flow recommendations, but does not see the model as a stand alone tool to provide long-term flow recommendations.

If not, how can model be improved?

(See detailed comments under Hydrology, Biology, and Statistics, below.)

1. Foundation (justification): *The justification is apparent. Fishery numbers are not increasing and DFG is asking the hard questions (as are others): why not? Pursing quantitative tools to assist in management actions and ongoing adaptive management frameworks is a laudable and necessary step.*
2. Logic: *The conceptual model and conversion of this to a quantitative tool in a spreadsheet environment is a method that has been employed by other agencies and entities (See CALFED, 2005, Appendix B). The methodology employed is transparent and the tool is readily used by stakeholders.*
3. Numeric representations: *Empirical models (e.g., regression equations) have strengths (based on real data) and weaknesses (sufficient data of sufficient variability are needed to form robust models). The challenge in the San Joaquin River is incorporating the appropriate factors to capture the spatial and temporal variability.*
4. Application and reliability: *The temporal and spatial variability in the San Joaquin River may not be fully represented through the application of linear regression equations based solely on spring flow conditions at Vernalis.*
5. Conclusions: *The tool is valuable in assessing several factors associated with flow conditions at Vernalis as this factor relates to fall-run Chinook production. However, there are other factors that may play a role. With modification, some of these other factors may be incorporated into the model, but more complex relationships may be required. As a result the current model may form an element of a suite of tools and relationships to formulate long-term flow recommendations, but as a stand alone model to formulate such recommendations it is probably insufficient.*
6. Calibration and validation: *The model is based on several sub-models (regression relationships). The nature of such empirical/statistical models makes calibration, in the true sense of deterministic model calibration, more difficult to explain. That is why complete presentation of sub-model development (data, comprehensive regression statistics, residuals, etc.) is a necessary step in documentation of the model. Recommend the comparison with historical data be called "validation" and drop the term "calibration." (See additional comments below.)*
7. Documentation: *Modest improvement in documentation could go a long way in supporting this model as a useful tool in identifying and testing hypothesis, as well as formulate the basis for future modifications and expanded capabilities.*
8. Testing (i.e. what monitoring could occur to validate or reject model predictions): *In general, the data are limited in space and time. One key outcome of this model is the modification, or better yet, the augmentation of existing monitoring programs to fill identified data gaps and test sub-hypothesis (e.g., that increased export increases smolt survival).*

Specific:

<u>Hydrology</u>

1. Are the methods used in the Model (including Model Report) relating to flow sufficiently documented? If not, what improvements can be made to improve documentation?

Flow data are only peripherally discussed in the documentation. The user is left to find his/her way through the spreadsheet model. For example the reference to source flow data (United States Geological Survey) is found in the 15th sheet of the model. Source of flow data should be referenced in the primary document.

2. What is the best metric (i.e. arithmetic mean, geometric mean, transformed data etc) that can be developed to adequately capture the variability in spring flow (i.e. magnitude and duration) on an intra-annual basis?

The period of record used in the model and sub-models is not clear. The regressions and/or other relationships are based on variable periods of time, e.g.,
- Mossdale smolt abundance: 1987-2003
- Delta Survival: 1994-2004 (including both HORB in and HORB out conditions)
- Smolt cohort production: 1988-2001
- Smolt outmigration pattern: 1988-2004
Rather than have this information included in an undocumented spreadsheet (SJR Model_Supporting Files.xls), it would be more useful to document these in the text of the report.

Once these periods are identified, then appropriate metrics can be determined. For example, perhaps a period of record arithmetic mean (or other metric) is developed…as well as a sub-period that is consistent/available among all data sets. Using the bullet points above, it may be useful to calculate the 1994-2001 mean for all data series so they can be assessed on a comparable time scale. Such an exercise may also point to data gaps or data limitations.

So as not to completely evade the question, basic summary statistics (mean, maximum, minimum, standard deviation) are not only useful, but also readily understood by stakeholders. If a particular metric provides additional information, e.g., particular excedance criteria, inter-quartile ranges, etc., they can be used so long as the definition and intention are clearly stated.

3. What improvements to hydrologic data utilization can be made to enhance model prediction performance reliability?

The 2004 flow data for flow at Vernalis should be updated with the latest USGS data (rather than using CDEC data which is provisional – this is a minor point). The Reviewer could not find a time series of Delta exports in any of the documentation. There were figures including export and export: flow ratio, but no tabulated export data paired with Vernalis flow.

4. Is there evidence of auto-correlation in flow calculations? If so, what is the affect? Does it need to be removed to improve model prediction (flow determination) reliability? If so, how can it be removed?

Review of an autocorrelation plot of residuals can provide useful insight. The Reviewer did not see a test for stationarity in any of the data (hydrological or biological).

5. Are there additional flow metrics, parameters, logic etc. that should be incorporated into model logic and function? If so, what are they and how can they be assimilated into the model (reference to logic and function)?

The reviewer is not convinced that Delta exports play no role as noted numerous times in the report (Pages 14,15, 17, 26). Actually, the report is not clear about this point, sometimes stating that export plays no role and at other times relying on the export:flow ratio to support a particular point. On page 15 there is a statement that "while the influence of Delta export upon SJR salmon production is not totally clear, overall it appears that Delta exports are not having a negative influence upon SJR salmon production they were once thought to have." This statement is contrary to the VAMP Annual Report:

> *"These relationships suggest that adult escapement in the San Joaquin basin is affected by flow in the San Joaquin River at Vernalis and exports by the CVP and SWP during the spring months when juveniles migrate through the river and Delta to the ocean." (SJRGA, 2006, page 61)*

Further, Figures 21 and 22(DFG, 2005) suggest that export, although inversely related to survival is much more sensitive than flow at Vernalis. Although not explored by the Reviewer, these findings suggest that there may be unanswered questions relating to export.

Biology

1. Are the methods used in the Model (including Model Report) relating to fish abundance and/or production sufficiently documented? If not, what improvements can be made to improve documentation?

The documentation provides a largely narrative description of the biological components of the model. The regression equation sub-models should be presented in equation and tabular form in the main documentation instead of requiring the user to open the spreadsheet to determine the main relationships. The supporting files spreadsheet, the model, and Tables 1 through 4 in the main report were not consistent in the form of the equations or the coefficients and constants values.

2. What improvements to fish data utilization can be made to enhance model prediction performance reliability?

The reviewer suggests that all available biological data and all data used in developing the sub-models (regression equations) be presented. All data sets include limitations, bringing such data limitations to light can help modelers and stakeholders interpret the results; identify data gaps; determine efficacy of the sub-models individually and as a group. Data limitations can range from limited data (e.g., relatively small sample size) to more complex issues such as identification of outliers (e.g., Mossdale smolt abundance estimate of 1989 is identified as an outlier but only briefly described).

3. Is there a way to improve how the model performs fish abundance prediction calculations and/or processing of fishery data?

A concern of the reviewer is that a wide range of regression based models are presented to support the general premise of the document – that spring flow is the primary driver of fall-run Chinook survival in the San Joaquin River – and to form the basis for the spreadsheet model. Some of these data are fit with power functions, others with exponential relationships, logarithmic functions, and some with linear relationships (e.g., see Figures 7-12, 18-22). The reason for selecting one form of the statistical equation over another is not sufficiently addressed. If there are specific non-linear and/or linear trends, the document would benefit from a more comprehensive discussion. One recommendation is to limit the range of models to one or two types and accept a lower correlation coefficient, but retain some consistency among the relationships. This is the case for the model (all based on linear relationships), but not in many of the other relationships supporting the model development.

4. Is there evidence of auto-correlation in fish related calculations? If so, what is the affect? Does it need to be removed to improve model prediction (flow determination) reliability? If so, how can it be removed?

Defer to other reviewers.

5. Does justification exist to include additional fish metrics, parameters, logic etc. in model logic and function (i.e. ocean harvest and/or Delta export entrainment)? If so, what are they and how can they be numerically assimilated into the model (reference to logic and function)?

In a complex system such as the San Joaquin River, Delta, San Francisco Bay, and Pacific Ocean, it may be difficult to identify the actual limiting factors – which may vary appreciably in space and time. That is, in any given year river flow, ocean conditions, tributary conditions (flow, habitat, and/or, temperature, predation) main stem San Joaquin River conditions (flow, habitat, and/or, temperature, predation), Delta export, and/or other factors may be individually a dominant factor or present a combination of stressors.

Statistical models based on limited variables do not explicitly include many factors by their very nature. Further, inter-annual variability may be under represented. These and other potential important processes are implicitly embedded in the constants and coefficients (e.g., and in y=ax +). Further, the linear models developed are unbounded, i.e., as flows increase, salmon numbers increase without limit. Realistically, in-river adult salmon density or other factor (e.g., disease) would ultimately limit production. This suggests that the model would benefit by an upper bound, or perhaps a revision of the model to a piecewise linear or nonlinear form (e.g., Figure 27, (DFG, 2005)) that represents density dependent mortality.

6. How can model representation of hatchery production, and underlying model logic, be improved upon?

See "General Comments" below.

7. Currently the model predicts a constant ocean survival rate (i.e. relationship between cohort abundance and Chipps Island abundance is constant). Is there a need to make this relationship variable? If so, how can this be numerically accomplished in model performance?

See "General Comments" below.

8. The model currently uses an adult replacement ratio of 1:1 as a numerically identified population health barometer. Is there a need to refine this ratio? What additional population parameter(s) could be incorporated into model logic and function?

See "General Comments" below.

<u>General Comment (Biology)</u>: *Including potentially important parameters, such as ocean survival or hatchery production, would provide a means to assess a broader array of potentially important factors. The questions posed herein are valid and present potentially useful additions to the model. However, the Reviewer is concerned that implementation of such models through a series of regression equations may not provide the sufficient flexibility to attain the ultimate goal of setting flow recommendations. Even through the collection of several additional years of data, the models would still be limited to "historical" conditions, thus limiting the predictive capability of the model to the range of sampled data. To encompass the broad range of potentially important parameters (ocean conditions; hatchery impacts; Delta conditions; flow and exports; San Joaquin River and tributary flow, temperature, habitat and other conditions, etc.) across multiple year types would may require a more rigorous modeling approach (e.g., life-cycle model).*

Statistics

1. Currently the model uses liner relationships between flow and fish production because this relationship provides the strongest correlation value. Is it necessary to include a model toggle switch, model logic, and mathematical functions, that allow users the option to test a variety of non-linear relationships between flow and fish survival and/or production upon model results?

Simply allowing the model to toggle among different relationships is a convenient feature for testing various relationships. However, caution should be employed in using the model for this purpose. The Reviewer suggests developing sub-models (regression equations) with care and identifying the relationships that exist among the data, determining if they make sense, testing them statistically, and documenting the assumptions and limitations prior to placing them in the spreadsheet model. For example, violations of linearity can be serious, and fitting a linear model to nonlinearly related data can result in considerable error, especially extrapolating beyond the range of the sample data – the overall spreadsheet model would not readily illustrate this weakness, but a comprehensive statistical assessment of the regression equation should provide such insight.

2. What is the statistical reliability of model out-put given that model predictions propagate? How can model reliability be improved?

(Defer to other reviewers.)

3. Is collinearity present in model logic and/or computation, and what influence does it have upon model results? If present how can it be removed?

(Defer to other reviewers.)

4. In some cases, model predictions for salmon production occur outside the empirical data set range used to develop the regression. What limitations in model reliability result?

(See response to question 1, above)

5. Presently smolt survival has a statistically significant regression correlation with Delta inflow level (i.e. less than 7,000). No statistically significant regression correlation for juvenile smolt survival and Delta export level exists. However when inflow to export ratio is regressed against flow survival, a moderate regression correlation occurs. Currently, exports are not included as a model prediction parameter. Should exports be included as a model prediction parameter (for smolt production)?

(See also hydrology comments above.) This question/comment appears to pre-suppose the relationship between Delta export and juvenile smolt survival. The model documentation actually identifies that "juvenile survival increases as exports increase" (DFG, 2005, pg 14, and Figures 19, 21, and 22). Further review of the VAMP annual report (SJRGA, 2006) suggest that there are still unanswered questions about the role of export on survival, and the fact that barrier operations at Head of Old River (HORB) apparently have an effect on survival and salvage indicate there is probably more to learn about this complex relationship. The recent wet year type will add a valuable data point, but one without the HORB in place. The limitation on placing the HORB at flows greater than 5000 cfs (or even the importance of having it in at flows greater than 5000 cfs), and the limited number of data points surrounding HORB placement or non-placement introduces uncertainty into the analysis. The DFG report has presented an interesting and useful hypothesis – that not only do exports not significantly affect San Joaquin River fall-run Chinook, but increased exports lead to increased survival – however, the supporting evidence does not appear sufficient to apply the model to set long-term flow recommendations at this time as per the documentation discussion (DFG, 2005).

6. Are the methods used in the Model (including Model Report) relating to statistical evaluations and/or model logic justification sufficiently documented? If not, what improvements can be made to improve documentation?

Including the regression information in the main documentation would provide a more complete document. Including plots of the residuals and standard error of the coefficients would provide the reader with additional information to interpret the results. For example, *the magnitude of the standard error of the coefficients in many of the relationships presented in the "SJR Model_Supporting Files.xls" are on the same order as the coefficients and constants themselves. (There are many relationships in this Excel workbook and the Reviewer did not attempt to determine which were applicable and which were not, rather simply looked through the regression summaries.) Also, recommend minimizing the generally narrative descriptions of the validity of relationships as "very strong", "strong," "strong correlation," etc. Such statements are subject to individual interpretation. Presentation of full statistical modeling results in tabular form with comprehensive discussion of results will do away with the need for such statements.*

7. What improvements to statistical use and application can be made to enhance model prediction performance reliability?

As per previous discussions, more description and interpretation of sub-model (regression equation) construction and performance.

8. There is substantial disagreement amongst scientists regarding the issue of density dependent mortality and its influence upon SJR salmon abundance (e.g. fall spawner abundance and spawning habitat availability: aka redd superimposition). In the absence of flow the relationship between spawner abundance and stock recruit appears to show density dependence (i.e. Beaverton-Holt or other density dependent type relationship). However when flow is included with spawner abundance, in the form of a multiple-regression using spawner abundance and spring flow regressed against adult recruits, a significant correlation exists suggesting that density dependence does not explain the variation in SJR adult salmon escapement abundance. How can this issue be resolved with data to date, or in the future if data insufficiency exists currently?

(See "Biology" question 6.)

9. How can the statistical relationships between flow and fish survival and/or fish production be improved?

(See previous comments in this section.)

Miscellaneous comments:

- *(Figures 13-15) Recommend identifying why the various traces in each graph start at different upstream water temperatures and discuss any associated implications for the various flow rates.*
- *(Figure 16) The figure is not convincing. If the data are censored to include only data over say 56^{o}F, the relationship is practically flat. There appears to be little data available, thus this figure indicates a potential data gap.*
- *(Figure 25) A statistical analysis of the Sacramento and San Joaquin Rivers salmon escapements may provide more insight than a simple graphical comparison. The San Joaquin River generally follows the trend (albeit considerably lower) of the Sacramento River. If these fish commingle in the ocean, and Sacramento River salmon are correlated*

to ocean harvest, then there is the potential for San Joaquin River fish to suffer a similar fate.

- *Model Calibration/Validation: See BDMF (2000) for additional details. http://www.cwemf.org/Pubs/Protocols2000-01.pdf*
- *No explicit temperature component in the model. Thus, even short term adverse "events" that can hamper smolt production (or other life stage) are not explicitly included.*

References

CALFED. 2005. *Review of the Biological Opinion of the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan*. Prepared by the Technical Review Panel for the California Bay-Delta Authority. December.

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Bay Delta Modeling Forum (BDMF). 2000. *Protocols for Water and Environmental Modeling*. BDMF 2000-01. January 21.

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